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A predictive model for recurrent consumption behavior: An application on phone calls

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ABSTRACT

Nowadays, companies use different datamining and prediction technologies in order to better forecast demands, consumers interests and business requirements. Anticipating the future helps businesses being proactive, managing resources and making intelligent decisions and investments.

In this article, we propose a prediction model for recurrent consumption behaviors based on inhomogeneous Poisson processes aiming at predicting users' future incoming and outgoing phone calls. The proposed model is lightweight in terms of processing power and storage requirement, capable of detecting users' recurrent phone calls and self-adapting to their changing behaviors and trends. The calls prediction model was implemented as a mobile application and evaluated in real world conditions. During 12 months, different configurations of our model were evaluated on a set of 7645 phone users in order to better tune it and measure its predictions quality.

1. Introduction

With the adoption and the proliferation of e-services, businesses rely on the collected data in order to analyze and understand consumers behaviors. Indeed, understanding consumption patterns helps businesses tailor their services, products and strategies to consumers' preferences and trends. In addition to personalization, such analysis enable businesses and service providers to anticipate changes in customers' expectations and consumption patterns and thus to proactively deal with them. In fact, analyzing and modeling individuals' behaviors and interactions is gaining an increasing interest among industrials, especially in highly concurrent fields where understanding and anticipating consumers preferences and trends is the key of success. In order to achieve this goal, researchers resort to analytical approaches such as datamining, statistical modeling and knowledge based techniques to overcome the uncertainties behind individuals behaviors and decisions. Such approaches were largely adopted in recommender systems in order to analyze customers' interests and predict their future consumptions and purchase decisions [1,2]. Nevertheless, other studies may also rely on empirical methodologies for behaviors modeling, simulation and analysis [3].

Some of consumers behaviors are periodic and thus, can be modeled and predicted in order to help businesses plan their offers and future strategies. In fact, modeling and consequently predicting individuals consumption with regard to goods and/or to brands may benefit both businesses and consumers. On the one hand, being able to predict consumers preferences makes businesses able to satisfy their needs with targeted products and personalized communication which increases their loyalty. Besides, modeling users recurrent purchases makes it possible to analyze and predict their loyalty over the time. On the other hand, consumers would benefit from personalized information and offers while spending less effort on searching for relevant content or goods [4]. Recurrent or periodic consumers behaviors can be seen in various domains such as energy consumption, food industry, clothing and communication. For example, consumers visit several types of stores periodically (e.g. coffee shops, restaurants, clothing stores, etc.). Even websites are visited periodically by users searching for information or for items to buy. In fact, some goods are purchased periodically by consumers (clothes, grocery, movies, etc.). Moreover, in the communication field, phone calls are partly recurrent and predictable and individuals may show similar consumption patterns but with some variations due to personal needs, contexts and intentions.

With current advances in communication and smartphones, service providers are looking to offer innovative and useful services for their customers via mobiles. Currently, telecommunication services providers, are becoming more interested in the adoption of

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recommender systems as a tool that enables them to personalize their products and services based on their customers' preferences similarly to e-commerce businesses [5]. In this context, recent researches in personalization and recommendation systems are focusing on hybrid approaches that unify existing theories. Hereby, Zhang et al. developed an hybrid recommendation system that helps customers selecting the most suitable mobile products and offerings based on their preferences [5]. Besides products and services recommendation, predicting users' future phone calls and consumption behaviors can also be seen as a new service that can benefit both individuals and businesses. On the one hand, it enables for instance telecommunication services providers to anticipate their network workload and increase their quality of service. Moreover, companies can use predictive models to forecast demands in order to better allocate their resources and investments. Furthermore, it enables them to analyze their customers communication habits in order to address the consumers churn problem and accordingly better tailor their offers [6]. On the other hand, predicting future phone calls helps customers in planning their communications, anticipating incoming calls and remembering important phone calls.

In this article, we propose a statistical model that predicts, for a given user, his/her future incoming and outgoing calls towards each of his/her contacts based on calls periodicity. The originality of the proposed model comes from its fine grained predictions, autonomy and small footprint. The model is experimented on a real life dataset in order to evaluate its performances and predictions quality in terms of precision and adaptability with the evolution of consumption behaviors.

The remainder of this paper is organized as follows. In Section 2, the main related works and their prediction methodologies are presented. Section 3 discusses our motivations with regard to the calls prediction problematic and enumerates the objectives of the aimed solution. Section 4 presents and formalizes our calls prediction model. The implementation of the proposed model and its architecture are detailed in Section 5. Section 6 details the experimental results of our proposition and compares the model's performances to several existing works. Finally, in Section 7, we analyze and interpret the obtained numerical results in order to present some insights regarding the different patterns of recurrent phone calls in several cultural and spatio-temporal contexts. The paper is then concluded with several potential extensions and improvements.

2. Overview of recurrent behaviors prediction

Consumers behaviors models and prediction approaches represent an important decision aid support helping businesses to harness the huge amount of available data and to foresee future consumption demand. In this context, several social and psychology researches are interested in understanding and modeling social interactions and human behaviors patterns [3]. In such researches, the main assumption is that individuals behaviors, interactions and decisions are largely recurrent, context-dependent and driven by habits which makes them predictable [4]. Thus, several researchers focus on modeling and predicting recurrent social interactions and periodic behaviors in order to propose better approaches and new applications.

Mobile and ubiquitous sensing data have been proven to be effective at predicting individuals' behavioral patterns. For instance, Pan et al. proposed a discriminative model capable of predicting users' mobile application installations based on their mutual phone calls and proximity data [7]. Their experiment has shown that heavily linked users are more likely to adopt the same products. In the same context, Singh et al. are also using mobile phone data such as calls and SMS logs in order to predict the spending behavior of couples [8]. Authors suggest that there are significant links between individuals' social interactions (inferred from phone calls, SMS logs and spatial proximity) and their spending behaviors (inferred from receipts and credit card statements). Besides, the researches carried by Eagle and Pentland have also proven that data generated by monitoring individuals mobile phones can be used to characterize the periodicity of social interactions and behaviors [9]. They distinguished two main frequencies of human interactions within a university campus ranging from one day to a week. However, other less frequent interactions may also exist in different contexts. In fact, Azam et al. also utilize contextual and wireless proximity data from mobile phones in order to detect repeated patterns in daily life activities and individual behaviors using the *N-Gram* technique [10]. These repeated patterns are used as a classifier in order to detect usual and unusual activities and interactions. The study shows that mobility data can be used to reveal individuals repeated and periodic behaviors whether they are short term daily routines or long term such as, monthly or yearly patterns.

Other researches with a broader objective focus on predicting phone calls arrivals at call centers as recurrent events. Brown et al. applied queuing theory in order to estimate the number of calls arriving at a call center [11]. Authors distinguished four types of calls and validated the adequacy of inhomogeneous Poisson processes when dealing with variable calls rates. Meanwhile, Avramidis et al. proposed several stochastic models of time-dependent arrivals in order to model phone calls arrivals in a call center [12]. The proposed models tackle the problematic of time-varying arrivals intensity and nonzero correlation between the arrival counts in different time periods within a day. Similarly, other researches rely on stochastic models in order to describe calls rate and predict the daily workload in a call center [13,14]. Probabilistic approaches such as autoregressive and Poisson count models were also used in order to take into account calls rate variability by estimating their intraday density [15–17].

De melo et al. focus on predicting phone calls durations in mobile networks [18]. In this work, the authors proposed the *TLAC* distribution fitting each user's calls duration patterns. Moreover, they define the *metaDist* model describing the calls duration behaviors of users groups in large mobile networks.

Harless and Kowalski developed a system to use in communication stations in order to predict future communication events (e.g. phone calls and/or emails) [19]. The system is based on correlations between past events and the future ones and includes two parts: (1) a component that analyzes past communications and determines the correlation logic between them and (2) a prediction component that examines a current incoming communication event and predicts the future outgoing one based on the correlation logic. Thus, the correlation database contains a set of association rules in the form $IncomingEventFromUser_i \Rightarrow OutgoingEventToUser_j$.

Kang et al. propose an outgoing phone calls prediction model based on users past actions and calling patterns [20]. The particularity of this work resides in the fact that the proposed model uses not only the user's outgoing calls log, but also his/her SMS log, schedule and phone sensors (e.g. WIFI, GPS, etc.). The model acts as a recommender system by predicting and proposing to the user the most probable number to dial at a given time.

Phithakkitnukoon et al. present a model that predicts, for a given user, his/her future incoming calls for the next 24 h [21]. The model evaluates the probabilities of receiving a call from a given contact u_i for each of the next 24 h. The system also predicts a user's outgoing calls and presents them as a list of the most likely numbers to dial. The calls predictor is based on the user's past communications and calls reciprocity with each contact. The model was applied on a training dataset containing a seven months calling history of 30 users and showed a 90.75% accuracy when